

Circuit arrangement and transistor control method

The present invention relates generally to the technical field of electrical or electronic circuit arrangements, in particular, a circuit arrangement and a method of regulating at least one transistor, especially of regulating the resistance value of at least a MOS transistor with vanishing DC modulation.

5 The regulation of a filter with the help of a reference frequency and a reference filter is described in the document EP 0 957 635 A2. The document EP 0 957 635 A2 particularly discloses a filter circuit to filter at the least a sound carrier in a composite video signal by means of at least one signal filter which has at least a filter frequency that can be adjusted as a function of the control signal.

10 According to the document EP 0 957 635 A2, the filter circuit comprises a reference filter whose filter frequency can be adjusted as a function of the control signal, which reference filter, when the filter frequency is tuned to the frequency of a reference signal supplied to it, rotates this reference signal with respect to its phase about a defined value; furthermore, a phase comparator is provided to which the output signal of the 15 reference filter and the reference signal are supplied.

From the output signal of the phase comparator is derived the power control signal so that the reference filter is tuned to the frequency of the reference signal; an output signal of a controlled oscillator of a phase-locked loop is used as a reference signal, which phase-locked loop is used for the demodulation of an audio signal modulated to the sound 20 carrier and whose controlled oscillator produces an output signal having the frequency of the sound carrier when the phase-locked loop is in the locked state.

Furthermore, the possibility is known from the state of the art of regulation with an external resistor and with a DC voltage. Two similar currents are then led through the external resistor and through an integrated reference MOS Metal Oxide Semiconductor 25 transistor. The voltage drops across the external resistor and across the integrated reference MOS transistor are compared by a comparator element, whose output voltage is stored in a condenser element and is supplied as a control voltage to the gate of the reference MOS transistor.

With this kind of regulation with the external resistor and with a DC-voltage, the steady-state, stable operating point is reached, if the MOS transistor has the same resistance value as the reference transistor, so that the voltage drops across the external resistor and across the internal MOS transistor are the same. The control voltage is 5 simultaneously supplied to all other similarly constructed, MOS transistors that are to be co-regulated.

If the actual operating condition of the MOS transistors to be jointly controlled deviates from that of the regulated reference MOS transistor, for example in the form of a vanishing DC voltage across only one of the MOS transistors, this will lead to an undesirable 10 and detrimental control deviation.

Starting from the aforesaid disadvantages and shortcomings and taking into account the outlined state of the art, the present invention has for its object to further develop a circuit arrangement of the type described in the opening paragraph and a method associated with this circuit arrangement of the type described in the opening paragraph, such that an 15 adjustment of resistance variations is also possible without control deviation for the case where the MOS transistor is operated with a diminishing direct current that is, with a zero direct current, and indeed without the aid of a reference frequency.

This object is achieved by an electric or electronic circuit arrangement having the characteristics given in claim 1 and by a method having the characteristics given in claim 20 6. Advantageous embodiments and effective further embodiments of the present invention are featured in the respective dependent claims.

According to the teaching of the present invention, a completely new kind of approach for an improved resistance control of at least a MOS transistor, whose DC modulation is equal to zero, is therefore made available. In this connection the present 25 invention depends on building the reference element a second time by corresponding insertion of two reference transistors having each a positive and an equally large negative storage operating point offset and an approximation to the desired operating point is realized by averaging these offsets, the principle of the present invention in other words corresponding to the substitution of the secant for the tangent of a curved graph.

The circuit arrangement according to the present invention and the method 30 according to the present invention follow the principle of regulating the resistance value of the at least one MOS transistor, which has a zero DC voltage drop, that is, a vanishing DC voltage which means, for example, that only an AC signal (Alternating Current) is supplied to the at least one MOS transistor that is to be controlled.

To regulate the resistance value of the at least one MOS transistor, according to the invention an emulation takes place with a direct current instead of an alternating current, for which purpose a positive DC voltage drop and a negative DC voltage drop are produced across the respective at least two reference MOS transistors. Then the (absolute) 5 arithmetical mean is calculated and compared with a DC voltage drop caused by at least one external resistor element. The voltage of the comparator element arising from this comparison is used to control the MOS transistor or the MOS transistors.

The circuit arrangement according to the present invention and the method according to the present invention have a multiplicity of advantages in that the present 10 invention makes it possible without the aid of a reference frequency to compensate for resistance variations without control deviation for the present application in which the MOS-transistor or the MOS transistors is or are operated with a vanishing DC voltage. Thereby, in a manner significant to the invention, the integration of steep-flank filters is realizable, the integration of which would not be realizable on the basis of high specification requirements 15 without compensating the variations.

Besides the above-described reduction of the control deviation of the MOS-transistor operated with a vanishing DC voltage and the above-described reduction of the range of deviation of the regulated filter, a cost reduction through the omission of a reference filter and a frequency generation is also obtained, so that the product according to the 20 invention is more than competitive with its higher precision of frequency and its lower cost compared to products of other manufacturers.

The present invention furthermore relates to a filter circuit comprising at least a circuit arrangement of the kind described above and/or operating by a method of the kind described above.

25 The present invention furthermore relates to a cable driver provided for an interactive exchange of data and signals, in particular having at least an integrated filter circuit of the kind described above and comprising at least a circuit configuration of the kind described above and/or operating by a method of the kind described above.

Such a type of cable driver is used, for example, in product families for cable 30 modems or for set top boxes and is used, for example:

- on the one hand, for suppression of high frequency signals (→ low pass function of cable drivers), possibly a suppression of harmonics or a mirrored signal of an analog signal coming from an upstream chip, and

- on the other hand, for providing a signal with a greater amplitude to a head station (→ amplification function of cable driver)

The present invention relates furthermore to the application at least of a circuit arrangement as described above and/or to a method as described above and/or at least to a filter circuit as described above and/or at least to a cable driver as described above

- 5 - in at least a cable modem and/or
- in at least a set top box and/or
- on the internet via a TV cable.

Functionally, cable modems are modems for cable distribution networks 10 which offer to the end user a bi-directional and highspeed access to the corresponding service provider; in this respect cable modems form an alternative to other broadband technologies, such as DSL (Digital Subscription Line).

To guarantee the bi-directionality, cable modems are constructed with an input 15 channel and a return channel that achieve downstream, i.e. from the head-end to the participant, a bandwidth of, for example, six Megahertz; in a 64 quadrature amplitude modulation (= what is called 64 QAM), transmission speeds of about 10 megabits per second up to about 30 megabits per second can be achieved over such a bandwidth. In upstream, transmission speeds of up to about 10 megabits per second are available for the return channel, in which, as a rule, quadrature phase modulation (so-called QPSK (quadrature 20 phase shift keying) is made use of.

There are cable modems with symmetrical transmission properties for the input channel and return channel and other cable modems with asymmetrical transmission properties. To support L(ocal) A(rea) N(etwork) applications directly, the transmission protocols correspond to those in local networks.

25 A set top box is a receiving instrument for digital pictures, digital data and/or digital sounds of all sorts. There are set top boxes, also called zapping boxes for uncoded channels, and additionally with common interfaces (CI) for coded channels.

The set top box is connected to the television receiver and decodes coded TV 30 signals, which the TV set cannot receive, into a corresponding standard signal. In addition, the set top box can also accept various additional functions such as descrambling, the resolution or the signal separation for personal computer (PC) applications such as the use of online services, and interactive distribution services such as pay per view, teleshopping, video on demand, or the like.

The present invention finally relates to the use at least of a circuit arrangement as described above, and/or a method as described above to regulate at least an integrated filter without reference frequency, in particular to regulate at least a transistor, more particularly to control the resistance value at least of a MOS transistor with vanishing DC modulation.

5 As was noted above, there are various possibilities to put the teaching of the present invention into practice in an advantageous manner. For this, on the one hand, the claims dependent on claim 1 are referred to, on the other hand, further embodiments, characteristics, and advantages of the present invention are commented upon in great detail below, with detailed embodiments illustrated in Figs. 1A, 1B, and 2.

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These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter

In the drawings:

15 Fig. 1A diagrammatically shows three transistor characteristics (drain-source current Id_s plotted against drain-source-voltage U_{ds}), for which the respective gate-source-voltage U_{gs} is constant;

20 Fig. 1B diagrammatically shows three transistor characteristics (drain-source current Id_s plotted against gate-source-voltage U_{gs}), for which the respective drain-source voltage U_{ds} is constant; and

Fig. 2 diagrammatically shows an embodiment of an electric or electronic circuit arrangement according to the present invention which operates according to the method of the present invention, elements and characteristics not being drawn to scale for reasons of easy visibility and recognizability of individual designs.

25 The same or similar designs, elements, or characteristics have been given the same reference symbols in figures 1A, 1B and 2.

30 With regard to the technical background of the present invention, it may be commented at first that the channel resistance (= $U_{ds}(\text{rain})$ $s(\text{ource})$ divided by $Id(\text{rain})$ $s(\text{ource})$) of a MOS transistor is dependent, on the one hand, on the gate-source voltage U_{gs} and, on the other hand, also on the drain-source-voltage U_{ds} , which can be inferred from the representation in figure 1A (= 3 transistor characteristics, for which the respective gate-

source voltage U_{GS} is constant and from the representation in figure 1B (= 3 transistor characteristics, for which the respective drain-source voltage U_{DS} is constant).

If now a MOS transistor in the filter is operated with a zero DC voltage across it, i.e. no direct current flows through the MOS transistor (only AC modulation), then the conventional control cannot be applied without control deviation, because the conventional control depends on a non-vanishing direct current (the operating point lies on a curved characteristic; the operating point is displaced in the case of DC modulation).

According to this theoretical introduction, an embodiment for a circuit arrangement 100 is represented in Fig. 2, by means of which the respective resistance values of P-MOS-FETs (= P-metal oxide semiconductor field effect transistors) 10, 12, 14 18, whose DC modulation is equal to zero, can be controlled.

This circuit arrangement 100 functions corresponding to the method according to the present invention, whereby in addition to a first reference element 10, 20, 70, which comprises the internal first reference MOS-FET 10 with a first offset from the operating point, a second reference element 12, 30, 40, 72, 76 is provided which comprises the internal second reference MOS-FET 12 with a second offset from the operating point equal in value but opposed in sign to the first offset; to approach and attain an optimum operating point as described below, an arithmetic average of the first offset and the second offset is taken.

In detail, starting with a reference voltage U_{REF} , which can be fed to the source connection 10s of the internal, first reference MOS-FET 10 and the source connection 12s of the internal, second reference MOS-FET 12, a reference current I_{REF} produces a voltage U_R with the help of an external resistor 78; the external resistor 78 is connected to the source connection 10s of the internal, first reference MOS-FET 10 as well as to the source connection 12s of the internal second reference MOS-FET 12 for this purpose.

A first current I_{11} equal to the reference current in conjunction with the internal first reference MOS-FET 10 produces a lower first voltage U_1 at the drain connection 10d of the internal first reference MOS-FET 10 than the reference voltage U_{REF} . An equal, but negative second current I_{12} in conjunction with the internal second reference MOS-FET 12 produces an equal, but opposite or reverse voltage drop, and thus a higher second voltage U_2 at the drain connection 12d of the internal second reference MOS-FET 12 compared with the reference voltage U_{REF} .

In this connection, the fact that the second current I_{12} is equal but opposed to the reference current I_{REF} and to the first current I_{11} is made clear by the direction of the

arrows in the Figures next to I_{ref} , T_1 and T_2 , indicating the technical direction of flow (from plus to minus).

The first voltage U_1 is now supplied to the input connection $20i$ of a first buffer element 20 and is buffered by means of this buffer element 20 . Correspondingly, the 5 second voltage U_2 is supplied to the input connection $30i$ of a second buffer element 30 and is buffered by means of this second buffer element 30 . Subsequently, the second voltage U_2 is inverted with respect to the reference voltage U_{ref} by an operational amplifier 40 , which is connected as an inverting amplifier with a gain factor of -1 to the inverted second voltage U_{2inv} .

10 For this purpose, the output connection $30o$ of the second buffer element 30 is connected via a resistor 74 to the first, i.e. negative, input connection $40i1$ of the operational amplifier 40 ; the second, i.e. positive input connection $40i2$ of the operational amplifier 40 is connected to the source connection $10s$ of the internal first reference MOS-FET 10 , to the source connection $12s$ of the internal second reference MOS-FET 12 , and to the external 15 resistor 78 , and is charged with the reference voltage U_{ref} .

In addition, a further resistor 76 is connected in parallel to the first, negative input connection $40i1$ of the operational amplifier 40 and to the output connection $40o$ of the operational amplifier 40 .

20 The buffered first voltage U_1 across a first resistor 70 , which is connected to the output connection $20o$ of the first buffer element 20 , and the inverted second voltage U_{2inv} across a second resistor 72 , which is connected to the output connection $40o$ of the operational amplifier 40 , are then averaged and supplied to a positive input $50i1$ of a 25 comparator 50 , to whose other, negative input $50i2$ the voltage U_r produced by means of the external resistor 78 is applied. For this purpose, the external resistor 78 is connected to the second, negative input $50i2$ of the comparator 50 .

30 The comparator 50 compares the mean value U_m with the voltage U_r caused by the external resistor 78 and charges or discharges at its output $50o$ a condenser 60 , which is connected not only to the output connection $50o$ of the comparator 50 , but also to the gate $10g$ of the internal first reference MOS-FET 10 , to the gate $12g$ of the internal second reference MOS-FET 12 , and to the respective gate $14g, \dots, 18g$ of all further MOS-FETs $14, \dots, 18$ to be jointly controlled.

The condenser voltage U_c serves as a control voltage for both reference MOS-FETs $10, 12$ and is supplied to their gates $10g, 12g$ and to the gates $14g, \dots, 18g$ of all further MOS-FETs $14, \dots, 18$ to be controlled. The control voltage U_c remains unchanged as

soon as the mean value U_m corresponds to the voltage U_r produced by means of the external resistor 78.

Before discussing the range of application of the circuit arrangement 100 explained above and of the method explained and associated with this circuit arrangement, it 5 may be supplemented, in view of the present invention, that in a M(etal) O(xide) S(emiconductor) -F(ield) E(ffect) T(ransistor) the drain connections and the source connections are, in principle, physically exchangeable; this signifies in the case of the circuit arrangement 100 explained above that the physical "identity" of drain connection and source connection, that is, the option inherent in the invention,

10 - to physically exchange the drain connection 10d and the source connection 10s of the internal first reference MOS-FET 10 and/or
- to physically exchange the drain connection 12d and the source connection 12s of the internal second reference MOS-FET 12,

lies within the disclosure and scope of protection of the present invention.

15 The range of application of the aforesaid circuit arrangement 100 and of the aforesaid method explained and associated with this circuit arrangement 100 extends, for example, to the regulation of integrated filters without reference frequency; thus the present invention is employable, for example, in cable drivers for interactive data and signal exchange. The fields of application of such a cable driver are, among other things, cable 20 modems, set top boxes or the Internet via a TV cable, in which this integrated circuit (IC) is employed.

KEY TO FIGURES:

100 Circuit configuration

10 First reference transistor, especially first M[etal] O[xide] S[emiconductor]-F[ield] E[ffect] T[ransistor] with vanishing DC modulation

10d Drain connection of the first reference transistor 10

5 10g Gate connection of the first reference transistor 10

10s Source connection of the first reference transistor 10

12 Second reference transistor, especially second M[etal] O[xide] S[emiconductor]-F[ield] E[ffect] Transistor with vanishing DC modulation

12d Drain connection of the second reference transistor 12

10 12g Gate connection of the second reference transistor 12

12s Source connection of the second reference transistor 12

14 Third transistor

14g Gate connection of the third transistor 14

18 Fourth transistor

15 18g Gate connection of the fourth transistor 18

20 First buffer element

20i Input connection of the first buffer element 20

20o Output connection of the first buffer element 20

30 Second buffer element

20 30i Input connection of the second buffer element 30

30o Output connection of the second buffer element 30

40 Operational amplifier, especially inverting amplifier with an amplification factor of -1

40i1 First, negative input connection of the operational amplifier 40

25 40i2 Second, positive input connection of the operational amplifier 40

40o Output connection of the operational amplifier 40

50 Comparator element

50i1 First, positive input connection of the comparator element 50

50i2 Second, negative input connection of the comparator element 50

50o	Output connection of the comparator element 50
60	Condenser element
70	First resistor
72	Second resistor
5 74	Third resistor
76	Fourth resistor
78	External resistor
11	First current
12	Second current
10 Ids	Drain-source current
Iref	Reference current
U1	First voltage or first voltage drop, especially positive (DC) voltage drop
U2	Second voltage or second voltage drop, especially negative (DC) voltage drop
U2inv	Inverted second voltage or inverted second voltage drop, especially inverted DC voltage drop.
15 Uc	Voltage of condenser element 60, especially control voltage
Uds	Drain-source voltage
Ugs	Gate-source voltage
Um	Mean voltage value, especially arithmetic mean voltage value
20 Ur	External voltage or external voltage drop, especially external DC voltage drop
Uref	Reference voltage